THE INFLUENCE OF TRACTOR TYRES INFLATION ON PHYSICAL SOIL PROPERTIES

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Abstract: With increasing size and weight of machines using in agriculture is also increases concern of soil compaction. Soil compaction affects adversely the yield in turn. Basic connection between the soil and the machine are the tyres. Choosing tyres in agriculture affects not only the economy but also the effect of the machine to the soil. Manufactures of tyres and agricultural equipment develop new design solutions to smaller negative impact of driving the machine on the soil. It also chosen tyre pressure can cause the different effects on soil properties. In this work, we focused on the influence of tractor passes at three different inflation pressures – 1, 1.5 and 2 bars on physical soil properties - on bulk density and porosity. The results show that passing tractor through the field has significant influence on soil compaction. The change of these parameters is particularly evident in upper layers of soil (up to 0.15 m). Results also indicate that tyres inflation pressure has statistically significant influence on soil compaction in the upper layers of the soil profile.

Key Words: soil compaction, bulk density, porosity, tractor tyres, Phaeozem

INTRODUCTION

The soil compaction is a threat to the long-term productivity of soil (Brevik and Fenton 2012). The farm tractors and field equipment are becoming ever larger and heavier (Chamen et al. 2013). The compaction may occur within the tilled layer, frequently just below the zone of tillage, or even at greater depths and the subsoil compaction may persist for decades (Schjønning et al. 2015). The soil compaction affects nearly all soil physical, chemical, and biological properties and functions (Batey 2009, Hamza and Anderson 2004).

Soil compaction is the densification of soil by application of mechanical energy (Holtz et al. 2010), which can occur naturally or driven by anthropogenic activities. The result is an increase of bulk density and a reduction of pore space (Horn and Smucker 2005, Keller et al. 2013), affecting the percolation of soil water as well as gas exchange or production. It may increase the soil resistance to root penetration (da Veiga et al. 2007, Fasinmirin and Reicher 2011), water deficit during dry spells by the rooting system (Grzesiak et al. 2012, Reichert et al. 2009), saturated hydraulic conductivity, and water storage (Bhattacharyya et al. 2006, Cavalieri et al. 2009). Soil compaction has been strongly linked to the loss of nitrogen by the accelerated production of greenhouse gases (e.g. N₂O) through denitrification in anaerobic conditions (Keller et al. 2013).

DeJong-Hughes et al. (2001) reported that excessive compaction reduces crop roots grow and consequently also the overall contact with the soil. It causes the reduction in the ability of plants to take up nutrients and poor water management. The stunted plants due to reduced root activity can be in dry years. In contrast, the increased denitrification can be due to low breathability in wet years.

In our article we focused on the influence of tractor tyres inflation on physical properties of soil – bulk density and porosity. It has been applied 3 tyre inflation pressures: 1, 1.5 and 2 bars. We compared the soil properties changes in the track machine and off track machine (zero variant). The described depths were 0.05, 0.15, 0.25, 0.35 and 0.45 m.
MATERIAL AND METHODS

Characterization of locality

The field measurements were carried out at the autumn in the year 2015 of land near the village Otmarov located in the district Brno-country (49° 10´ N and 16° 67´ E), around 12 km S of Brno. The elevation of the land is 193 amsl.

Grain size composition of the land for each depth is presented in Table 1. The soil type is Phaeozem.

Table 1 The grain size composition of the land

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Faction</th>
<th>Value (wt %)</th>
<th>Moisture (%vol.)</th>
<th>Depth (m)</th>
<th>Faction</th>
<th>Value (wt %)</th>
<th>Moisture (%vol.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>Clay</td>
<td>29.30</td>
<td>30.59</td>
<td>0.35</td>
<td>Clay</td>
<td>30.98</td>
<td>31.90</td>
</tr>
<tr>
<td></td>
<td>Silt</td>
<td>35.02</td>
<td></td>
<td></td>
<td>Silt</td>
<td>31.90</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sand</td>
<td>35.68</td>
<td></td>
<td></td>
<td>Sand</td>
<td>37.12</td>
<td></td>
</tr>
<tr>
<td>0.15</td>
<td>Clay</td>
<td>31.24</td>
<td>31.61</td>
<td>0.45</td>
<td>Clay</td>
<td>34.34</td>
<td>34.78</td>
</tr>
<tr>
<td></td>
<td>Silt</td>
<td>31.74</td>
<td></td>
<td></td>
<td>Silt</td>
<td>34.78</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sand</td>
<td>37.02</td>
<td></td>
<td></td>
<td>Sand</td>
<td>30.88</td>
<td></td>
</tr>
<tr>
<td>0.25</td>
<td>Clay</td>
<td>34.36</td>
<td>30.29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Silt</td>
<td>33.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sand</td>
<td>32.42</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend: clay <2 \( \mu \)m, silt 50–2 \( \mu \)m, sand 2000–50\( \mu \)m. Moisture – average of all samples from the place “in tractor rut” and “between the tractor ruts”.

Experimental design and laboratory

It was chosen appropriate stretch of land on the locality in order to the load on the tractor’s wheels evenly distributed.

The tractor was fitted with a disc harrow. The disc harrow was divided into a working position for uniform distribution of load. Its height above the land remained in the maximum lift position of the rear three-point system of the tractor.

It was elected German production tractor Deutz-Fahr for measurement, specifically Agrotron X720 model. The tractor had at the time of measurement supplemented with all operating fluids. The carried disc harrow was clamped in the rear three-point hitch. The weight was used in the front three-point hitch for ballasting the tractor. The tractor parameters are given in Table 2.

Table 2 Selected parameters of the tractor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor weight (kg)</td>
<td>10 160</td>
</tr>
<tr>
<td>Tractor front ballast weight (kg)</td>
<td>1 100</td>
</tr>
<tr>
<td>Specification of tractor front tyres</td>
<td>600/65R38</td>
</tr>
<tr>
<td>Specification of tractor rear tyres</td>
<td>710/70R42</td>
</tr>
<tr>
<td>Weight of disc harrow (kg)</td>
<td>3 490</td>
</tr>
</tbody>
</table>

The tractor tyres were inflated to 3 different pressures – 2 (A), 1.5 (B) and 1 (C) bar. The measurement section for each tyre inflation pressure was 10 m. The speed of the tractor at passing
through measurement section was 10 km/h. The inflation pressure was controlled using tyre filler with a pressure gauge manufacturer from Aerotec.

The soil samples were sampled in tractor rut (I) after crossing mechanization. As a zero variant were used samples collected between the tractor ruts (II). The zero variant was determined for each inflation pressure.

The core samples were sampled into the Kopecky rollers (volume 100 cm$^3$). The depths of samplings were 0.05, 0.15, 0.25, 0.35 and 0.45 m. Soil samples were taken in row spacing within 4 repetitions for each variant. Samples were processed according to the methodology of the Central Institute for Supervising and Testing in Agriculture (Zbíral 2002). The laboratory results identified values of bulk density and porosity. The bulk density and porosity are some of the physical properties, which are used to evaluate the physical condition of the soil in the Czech Republic. The limit for this soil type is for bulk density $< 1450$ kg/m$^3$ and for porosity $> 45\%$.

Statistical analysis

The data obtained were subjected to Grubbs test extreme deviations. Results of bulk density and porosity were statistically compared. The values were analyzed by ANOVA with interaction. Post-hoc tests were carried out by Tukey HSD test at the level $p < 0.05$. The statistical software was used Statistica 12 (StatSoft, USA).

RESULTS AND DISCUSSION

Bulk density

The graphical results from ANOVA are shown in Figure 1. The Figure 1 shows the significant difference between bulk density at the depth 0.05 m for sampling I and II. Value of II indicated significant statistical difference between the depths of 0.05 and 0.15 m. similar fact was found in I. There was the statistically significant difference between the depths of 0.05 and 0.15 m for all three variants of inflation pressure. While the bulk density at the depth 0.05 m had values with limit, the value at the depth 0.15 m was longer above the threshold. Other significant differences were apparent between the depths 0.25 and 0.45 m for all inflation pressures and especially by II.

Figure 1 Dependence of bulk density on the depth and tyres inflation pressure

Differences among bulk densities for sampling I and II are shown in Figure 2. Influence and statistically significant difference among tyre inflation pressure 1 bar, 1.5 bar and 2 bar is evident from the figure. Statistically significant differences were found out for 0.05 m and 0.15 m depth.
Porosity

The Figure 3 shows the porosity for all tyres inflation pressures. As the bulk density and porosity values together correlate, can be observed the similar trend as in the previous graph. The relationship between porosity and bulk density has the character of an inverse. It might therefore be expected that the porosity will have the highest value by the depth 0.05 m. This trend was confirmed. The statistical significant difference was observed between the depths 0.05 and 0.15 m I and II by variants A, B and C. The statistical difference was observed also between the depths 0.25 and 0.45 m, similar to the bulk density. The difference was more pronounced by II. The statistical differences by I were only by variant A and C.

Figure 3 Dependence of porosity on the depth and tyres inflation pressure

Due to the limited pages of this article, ANOVA graphical results from differences among porosities for sampling I and II are not shown, nevertheless the results are very similar as in the case of bulk density. It was found out statistically significant effect of tyre inflation pressure on porosity in depth 0.5 m and 0.15 m.

According Kostelanský (2004), aerating increases generally the porosity values from 50 to 60%. Our field was aerated twice to similar depths 0.10 and 0.12 m before sampled. The porosity value was
50–65% by our field (see Figure 3). Subsequent reduction of porosity sampled in tractor rut was thus demonstrably the cause of the passage tractor. Figure 3 also shows that the total porosity did not get worse with increasing depth. Some studies reported that the aeration of soil into more of the same or similar depths may be manifested by creating a so-called bottom plough. Bauder et al. (1981) detected the compacted layer just below the depth of tillage disc cultivator. Their experiment was carried out on clayey soils and it was ten years consecutively grown corn. The disc cultivator to the depth 0.08 m was the only represented the deeper aeration the soil processing for each year. Our field was aerated to limited depths of minimalization technologies in recent years. The allegations of creating bottom plough suggest mainly results in Figure 1 and Figure 3. The value of the bulk density and porosity in the depth 0.25m between the tractor ruts was exceeded to the limit value.

It was also apparent subsequent change both monitored physical soil properties of over limit at the depth 0.25 m to limit values at the depth 0.45 m. So, the state land before the crossing has a significant impact to the pressure spreading under the tyres and the subsequent compaction.

As already mentioned, the bulk density became the maximum just above the limit values by the depth 0.15 and 0.25 m (see Figure 1). The values reached between 1 500 and 1 650 kg/m³. Svoboda and Červinka (2013) achieved the similar values of bulk density in their work.

CONCLUSION

Soil compaction is the problem of contemporary agriculture throughout the world. The causes of this condition are more. However, man and his intensive farming methods with the used technique have the great merit on it. The effect of a tractor on the soil significantly affects the choice of tyres – width, diameter, tread, but also tyre inflation pressure. It is also confirmed by results from measurements. Passing tractor through the field has significant influence on the parameters characterize soil compaction - bulk density and porosity. The change of these parameters is particularly evident in upper layers of soil (up to 0.15 m). The biggest changes of bulk density and porosity were occurred mainly in the lowest depth 0.05 m. In the deeper layers was not observed significant changes. However, primarily bulk density and porosity of the upper layer of soil are very important for the root systems of plants (particularly in the beginning of plant growth). One possible solution is minimization of number crossing on the field and also change tyres inflation pressure of tractor. Results from ANOVA show that tyres inflation pressure has statistically significant influence on soil compaction in the upper layers of the soil profile.

From this perspective, it is advantageous to use the modification of tyres inflation pressure not only for improvement traction of the tractors, but also to reduce the negative effects on the soil.

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REFERENCES


